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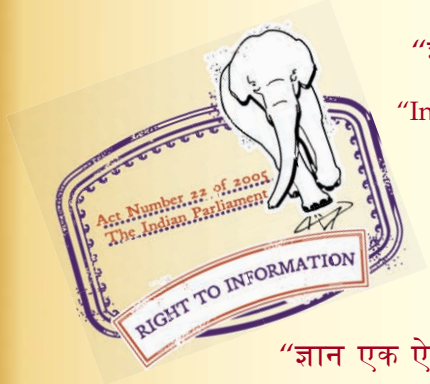

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CODE OF PRACTICE FOR CATHODIC PROTECTION OF STEEL STRUCTURES

PART III SHIP'S HULLS

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CODE OF PRACTICE FOR CATHODIC PROTECTION OF STEEL STRUCTURES

PART III SHIP'S HULLS

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CODE OF PRACTICE FOR CATHODIC PROTECTION OF STEEL STRUCTURES

PART III SHIP'S HULLS

0. FOREWORD

0.1 This Indian Standard (Part III) was adopted by the Indian Standards Institution on 27 October 1977, after the draft finalized by the Corrosion Protection Sectional Committee had been approved by the Structural and Metals Division Council.

0.2 Anti-corrosive paints applied to ship's hull fail to provide complete protection to the hull from the corrosive attack of seawater. During painting, holidays are left on the portions resting on the keel blocks. Paint coatings, normally applied under conditions existing in the dry dock, contain pores and are susceptible to various degrees of water permeation, and are more prone to detachment due to turbulence in the stern area. The coating may loosen, blister or undergo physical damage during active service thus exposing areas which become more vulnerable to corrosion.

0.3 Cathodic protection, when applied in conjunction with protective coating, ensures freedom from corrosion and, therefore, provides longer life of the hull.

0.4 This code of practice is being issued in parts. This part covers the cathodic protection of ship's hulls. The other parts are as follows:

Part I	General principles
Part II	Underground pipelines
Part IV	Galvanic protection of dock gates, caissons, piers and jetties

1. SCOPE

1.1 This standard (Part III) deals with the cathodic protection of underwater hulls of active ships including its application during fitting-out period or when laid up. It should be read in conjunction with IS : 8062 (Part I) - 1976*.

*Code of practice for cathodic protection of steel structures: Part I General principles.

2. GENERAL

2.1 Cathodic protection of ship's hulls should preferably be considered at the design stage. With the exception of fresh water fitting-out dock, the conditions as obtained in other docks are highly corrosive. Ships, therefore, should be provided with cathodic protection at such sites during the fitting-out period till the first docking.

3. METHODS OF CATHODIC PROTECTION

3.1 There are two methods of cathodic protection for ships or other marine structures in immersed condition, namely: (a) cathodic protection by galvanic anodes, and (b) cathodic protection by impressed current system. Both the systems are applied to ships or marine structures which have been provided with a suitable protective coating, such as paint.

4. CHOICE OF CATHODIC PROTECTION METHOD

4.1 There is no general rule for selecting a particular method of cathodic protection. The choice between the two methods should be based upon the prevailing circumstances and overall economy.

4.2 Ships of small size or low speed may preferably be fitted with galvanic anodes, while ships of larger size and greater speed may be fitted with impressed current system. In larger ships, technical staff are normally available who may supervise the operation of the impressed current system.

4.3 The relative advantages and disadvantages of the two methods as given in Appendix A, should be taken into consideration while selecting the protection system.

5. FACTORS AFFECTING DESIGN

5.0 The following aspects should be taken into consideration while designing the cathodic protection system.

5.1 Installation — Installation and/or maintenance of galvanic anodes and other work may only be carried out when the ship is in dry dock. Galvanic anodes should, therefore, be designed for a life which is a multiple of the interval between successive dockings of the ship.

5.2 Effect of Drag — The possible increase in hull resistance due to fitting of anodes should be considered at the design stage. The anodes should be so shaped and positioned as to reduce turbulence in the streamlines around the hull. Anodes may also be grouped and fitted by streamlining so as to reduce drag. Close spacing, however, reduces current output compared to widely spaced anodes.

5.2.1 Drag increases with speed and hence the ship requires increased shaft horsepower to maintain the enhanced speed. Drag effect is relatively more pronounced with the galvanic anode system and it is almost negligible with the impressed current system.

5.3 Corrosion Rates at the Stern — Corrosion rates are normally higher at the stern area due to increased turbulence near the propellers and formation of galvanic cell between the bronze propellers and the steel hull. Careful consideration should, therefore, be given to the design of the cathodic protection system for the stern area.

5.4 Hull Potential — If the hull potential is made considerably more negative than the protective potential, the paint applied on the hull may be damaged. The application of cathodic protection should be considered along with the quality of paint which should be compatible with the protective potential range.

5.5 Current Requirements — Current density required by a ship for cathodic protection, is generally variable and depends on (a) speed, (b) immersed area, (c) quality and condition of paint, (d) bare areas, (e) salinity, and (f) temperature. These factors should be taken into account in the design of control equipment for the impressed current system.

6. PAINTING OF SHIP'S HULL

6.1 The underwater hull of a ship should be painted with the approved anti-corrosive paints, following the recommended practice for painting ship's bottom.

6.1.1 Generally oil-based and oleoresinous paints are not compatible with cathodic protection, for such paints are susceptible to softening and blistering by the alkali generated at the hull (cathode) due to electrolytic action. Heavy duty coatings are desirable and should always be used where the hull potential may become more negative than −900 mV, with reference to silver/silver chloride or saturated calomel electrode. The heavy duty coatings are based upon epoxy resin, chlorinated rubber, vinyl or other alkali resistant material.

6.1.2 According to the availability of materials, cost and other factors, the entire hull or the areas around the anodes may be protected with the heavy duty coatings. The hull surface should be adequately prepared and coating thickness should conform to the specified limit.

6.2 Current Density for Protection — The current density required to protect the wetted area of the painted hull of a ship may vary from 10 to 50 mA/m^2. For cargo ships, the wetted area should be calculated on the maximum draught.

7. APPLICATION OF GALVANIC ANODE SYSTEM

7.1 Anode Material — The galvanic anode material may be made of alloys based on magnesium, zinc or aluminium. The application of aluminium anodes is preferable to other types of anodes for cathodic protection from the point of view of availability.

7.2 Design and Installation of Anodes — Galvanic anodes should be provided with steel inserts suitable for welding or fitting by means of studs. Anodes are normally welded directly on the hull. Where welding and rewelding may affect the hull plate, a small doubler plate may be welded on the hull. The anode may be conveniently welded to the doubler plate or fitted with stud-on type anodes. Studs should be securely welded to the hull. Nuts are used to lock the anode. Tack welding of the nut to the insert is desirable. The cavity around the stud and nut should be filled up with a putty. Anodes which are to be fitted in midship section should preferably be fitted on both sides of the bilge keel.

7.2.1 Safety precautions should be taken prior to welding anode inserts or studs on the hulls of ships whose tanks or adjacent tanks may contain or had contained oil and fuel.

7.3 Mass of Anode Material — The mass of the anode material required to cathodically protect a ship from marine corrosion depends upon: (a) current density required per unit area of wetted surface of the ship, (b) current capacity of the anode, and (c) the period for which cathodic protection is required.

7.3.1 Knowing the current capacity of the anode in terms of ampere year per unit mass (kg) the total mass of anode required may be calculated for the entire wetted area for one year or a multiple of the period between dry dockings. The additional current required for the bronze propellers should also be taken into consideration. Normally one to three years of cathodic protection of the hull is envisaged. As the anodes are consumable their replacement during dry docking would be necessary. It may not be necessary to replace all anodes during the same docking.

7.4 Number and Distribution of Anodes — The number of anodes shall depend upon mass and dimension of individual anodes and ease of handling. The aspects of drag and satisfactory distribution of the anodes shall also influence the number. Adjustment in the number of anodes may be necessary. Distance between individual anodes should be usually 6 to 7 m. Anodes may be fitted in line. Closer spacings may be necessary at the stern or when the anodes are grouped together. In the midship area it is not advisable to carry out welding as it may damage the hull plating. The normal practice is to fix the anodes on the bilge keel or to weld them on doubler plates. Normally 15 to 20 percent of the total quantity of anode material is installed at the stern area. The remaining anodes are distributed along the side of the hull including the bilge keel.

7.5 Protection of Anodes During Painting — The anode surface should not be painted on any occasion. During hull painting, anodes should be suitably marked. If any paint or other coating material falls or is found to adhere to the anode surface, it should be cleaned by means of a suitable solvent or scraped off.

7.6 Evaluation of Hull Potential — The hull potential of an active ship or a ship during fitting out or when laid up may be obtained both before or during cathodic protection by means of an external reference electrode. The protective hull potential should be between −750 mV to −850 mV with reference to silver/silver chloride electrode, or −800 mV to −900 mV with reference to saturated calomel electrode, or +250 mV to +150 mV with reference to zinc electrode.

8. IMPRESSED CURRENT CATHODIC PROTECTION SYSTEM AND ITS INSTALLATION FOR SHIP'S HULL

8.1 General — In the impressed current cathodic protection (ICCP) system, direct current is supplied to respective insoluble anodes fitted on the underwater hull of the ship. Hull potential is measured with respect to reference electrodes which is permanently fitted on the hull. Protective hull potential is closely maintained to a preset reference potential in the electrical control equipment which should be so constructed that a dc output is automatically adjusted to the value required to maintain the required protective potential of the hull.

8.2 Control Equipment — When ac supply is available on the ship, a transformer-rectifier unit is used to obtain dc. The equipment is designed to provide adjustable low-voltage dc output. Protective current is normally required to be adjusted so that the protective hull potential is attained and maintained. Automatic control system is preferable to manual control though the latter system is also often included in the automatic equipment. As the impressed current system has to operate continuously throughout the active period of the ship, the equipment should be of robust construction and efficient in design. Power supply may also be obtained from other sources, such as dc supply. All electrical plants, cables, switchgears, etc, should conform to normal safety requirements.

8.2.1 *Automatic Control System* — Various types of automatic potentiostats, transformer-rectifier equipment are available based on saturable reactors, thyristors or transistors. They control the current output so that the potential of the hull of the ship is maintained close to the preset value designed on the basis of the optimum protective potential and siting of the reference electrodes. A number of anodes may be connected to a single control unit. Details about the control unit and their number, the number and type of anodes, and the reference electrodes may be worked out by the designer in consultation with the user taking into account the class of the ship and the paint system used.

8.3 Hull Perforation — Hulls are required to be perforated at all points where anodes and reference electrodes are to be installed. The positions of perforations should be decided upon by the designer of the cathodic protection system and the shipbuilder/user in such a way that oil, fuel and even water ballast tanks are avoided. The holes should be shielded from inside with gadgets having appropriate cable entry system, and watertightness, by means of appropriate glands, should also be ensured.

8.4 Anode — The commonly used anode for use with impressed current system, consists of lead alloy or platinized-titanium. Both the anodes may be used at high current density.

8.4.1 The anode material should be mounted on backing insulating shield for hull mounting and should be provided with power cables. The anodes may consist of long strips, discs or may be of oval design, and should be so shaped that it offers least resistance to water-flow. Necessary attention should be paid to building-up of insulating shield around the anode.

8.5 Reference Electrodes — The reference electrode may be of high purity zinc or silver/silver chloride type. It should be secured to, but insulated from, the hull, and should be provided with suitable cables.

8.6 Number of Anodes — The anodes required for impressed current system are small in number compared to the galvanic system. Usually 2 to 5 anodes are adequate for a small to large ship. For example, four anodes are required for a ship of 13 000 DWT.

8.7 Number of Reference Electrodes — The number of reference electrodes usually varies from 2 to 5 depending upon the size of the ship, and should be worked out by the designer on the basis of past experience.

8.8 Location of Anodes and Reference Electrodes — On small ships, anodes may be installed a little forward of the midship and near the stern. On larger ships appropriate distribution may be made around the wetted hull area, keeping in view the requirement of high current density at the stern.

8.8.1 For cargo tanks, anodes should be installed forward and aft of the cargo tank space. Sometimes, anodes may be fitted only at the aft of the cargo tank.

8.8.2 The reference electrodes should be installed a few metres away from the anodes. It is necessary to mount the reference electrodes on the ships hull at suitable predetermined positions.

8.9 Insulating Shield — In the impressed current system the anodes receive high current density which may damage the paint in the vicinity of the anodes as it produces high negative potential. The area around the anode should, therefore, be protected by means of a specially prepared insulating layer.

8.9.1 The anode shield may follow the shape and size of anode. Usually a circular shield is chosen for oval or disc-shaped anode, while rectangular types of anodes may have rectangular shield.

8.9.2 The size of the insulating shield should be such that the potential at any point adjacent to its outer edges is unlikely to break down the adjacent paint. The insulating shield may be built of high-duty coating about 1 mm thickness consisting of glass-reinforced epoxy or polyester resin.

8.9.3 It is essential to apply anti-fouling paint to the anode shield but it is imperative that no paint is applied to the working surface of the anode.

8.10 Impressed Current Circuit — The positive terminals of dc output in the transformer-rectifier unit are connected to the respective anodes fitted on the underwater hull. Cables are taken through a junction box suitably positioned. Cables should be of approved quality, and should not run through oil, fuel or water ballast tanks. The negative terminal of the dc output should be connected to the hull of the ship by means of an appropriate power cable. The reference electrodes should be connected to the control unit according to the manufacturer's instructions.

9. BONDING

9.1 As the propellers are made of nobler metals than the hull of the ship, propeller shaft should be bonded to the hull structure, by means of appropriate slip ring and brush arrangement. The resistance of this bond in service should be less than 0·01 ohm. Whenever the propeller shaft is in bonded condition, cathodic protection system should be in operation. Otherwise a galvanic cell is set up which may cause corrosion of the hull. The propeller themselves receive cathodic protection due to bonding which reduces its general corrosion as well as impingement attack.

10. CATHODIC PROTECTION OF SHIPS DURING FITTING-OUT OR WHEN LAID UP

10.1 During Fitting-Out — The application of galvanic cathodic protection system during the fitting-out period by suspending sacrificial anodes in the seawater on either side of the ship is considered convenient and practical as these anodes may be hauled on board as and when required or lowered back by altering their number and position, when the ship is moved to other sites. The anodes should be hung at a distance of about 3 m from the ship's sides.

10.1.1 It is not desirable to employ impressed current cathodic protection system during fitting-out period even though the ship might have been provided with the complete installation system at the construction stage. Leakage of current often occurs during welding operation on board ships, and interferes with the operation of the impressed current system.

10.2 When Ship is Laid Up — Choice has to be made if the hull is to be protected by suspended galvanic anode, hull mounted anode or impressed current system. The hull mounted anodes may have to be replaced in dry docks, while suspended anodes may be removed at sites. At permanent moorings, galvanic or impressed current anodes may be laid on sea bed provided clearance between the galvanic or anodes and the keel at low water is sufficient to prevent damage of the painting on the hull.

10.3 Interaction with Unprotected Ships — Corrosion interaction may arise due to cathodic protection of a ship, if it is moored alongside an unprotected vessel or jetty, or due to cathodic protection on jetties which may cause interaction while unprotected ships are alongside. In either case, the interaction may be reduced by bonding the unprotected ship to the protected ship or jetty by means of steel mooring ropes.

APPENDIX A

(*Clause* 4.3)

COMPARISON OF GALVANIC ANODES AND IMPRESSED CURRENT SYSTEM

Galvanic Anode System	*Impressed Current System*
1. Relatively simple to install.	1. Needs careful design for installation.
2. Require usually many anodes.	2. Requires a smaller number of anodes.
3. Anodes are in electrical contact with structure through welded inserts or bolts. Does not require anode shield.	3. Anodes are effectively insulated from the structure. Requires anode shield.
4. No perforation on the hull or structure is necessary. Anode may be welded or bolted to the structure.	4. Hull/structure perforations necessary.
5. Anode forms galvanic cell with the hull/structure. No other source of electric supply is necessary.	5. Direct current is required to be delivered to the anode in controlled manner from a transformer-rectifier or dc supply.
6. Introduces drag on ship's hulls.	6. Drag is negligible.
7. Use is generally restricted to well-coated structures, because of limited available current.	7. May be applied to a wide range of structures, including, if necessary, uncoated structures.
8. Anodes are consumable. Requires periodical replacement.	8. Anode is durable and insoluble. Does not require replacement.
9. Hull/structure potentials require to be measured with the aid of external reference electrode.	9. Hull potential is measured and controlled with the fixed reference electrode on the hull/structure, which is an integral part in the control system.
10. Initial cost is low.	10. Cost of sophisticated impressed current system is high.

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